Shipping Industry at Crossroads – Compliance to 2020 Low Sulphur fuel – Challenges & Alternatives (?) - A Hobson's Choice

Abstract

There has been steady reduction in the Sulphur content of fuel as per Regulation 14 ever since MARPOL Annex VI – Prevention of Air Pollution from ships was adopted in 2005. The step wise reductions began from the year 2010, 4.5 %, then 3.5%, (m/m), both globally and in Emission Control Areas (ECA) from 1.0% to 0.1%(m/m). The new agreed Sulphur cap which will be enforced globally from 1st January 2020 has been pegged at 0.5%(m/m) in compliance to Regulation 14 of MARPOL Annex VI. This has been hailed as a significant reduction from 3.5%, which is currently in place.

To the ship owners it has been a ***"Hobson's choice"***, why? does he have a choice at all? The transition to 0.5% S fuel is likely to cause upheaval to global marine industry. Notwithstanding above, the challenges are many for him to operate his fleet without pitfalls, in the wake of many uncertainties, which are, availability of compliant fuel, consistency across all the bunkering facilities, formulation of standards by the International Organization, behavior of low Sulphur fuel yet to be understood by the operators, technology yet to be fully evolved, are engine manufacturers of both propulsion and auxiliary engines, fully seized of the impact of such a fuel on engine components, namely fuel pumps, fuel injectors, fuel filters etc. The shipboard equipment also includes even boilers.

What strategy the ship owner will adopt will defer from ship to ship, as every ***ship has her own soul.*** **It will be a tough** call to make choice between, low Sulphur fuel, use of Exhaust Gas Cleaning System (Scrubber), Liquified Natural Gas(LNG) as fuel, low Sulphur Marine Gas Oil (MGO), other alternative fuels such as ethanol and methanol, but these are unlikely to be available in the immediate future.

The paper tries to highlight the challenges and possible ways of mitigating these challenges, without influencing ship owner's decision or arguing in favour of one option over the other.

Key words: Hobson's choice, low Sulphur fuel, EGCS, MGO, LNG

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1. Initial remarks

IMO has done something no one has done before: set an absolute target for emission reductions for an entire industry. It is a landmark achievement in the effort to reduce emissions, and something that every other industry should look to for inspiration

The introduction of the new global sulphur cap in 2020 is causing nothing short of a paradigm shift in marine fuel. It is more than just another regulation — it is a complex challenge, and how you choose to comply may ultimately impact the future competitiveness of your assets. There is a great deal of uncertainty related to enforcement, fuel availability and technological solutions.

It is challenging to make exact predictions regarding the most cost-efficient approach. Every ship is different and so is its operational profile. The ultimate decision between HFO and scrubber, distillate fuel (MGO), LNG, low-sulphur fuels (0.50 % S) or other, alternative fuels should to be evaluated individually. The exploration of battery power on some class of ships such as oil tankers operating near the coast should not be ruled. Considering all the above available options one thing which emerges from such a scenario is that trade movement through sea routes is bound to be an expensive proposition, eventually raising the cost of goods at the end of the supply chain, i.e. the end use customer.

1.1 MARPOL Annex VI

MARPOL Annex VI entered into force in May 2005, providing comprehensive regulations for the prevention of air pollution from ships. This paper only covers issues related to the use of low Sulphur fuel to be introduced from 1st January 2020. Figure 1 below shows step down reduction in allowable Sulphur limits.

MARPOL Annex VI defines SO_x Emission Control Areas (SECA), and the procedures for implementing new such areas. Presently the Baltic, the North Sea and the English Channel are affected, the main features being

- Maximum permissible sulphur content 1.5 %, or alternatively exhaust gas cleaning, or “any other technological method”. This Guideline focuses on the first option.
- Fuel changeover to be recorded in log book.

MARPOL Annex VI entry into force:

- 19th May 2004: Ratified.

- 19th May 2005: Entry into force as such.
    - Sulphur cap 4.5 % worldwide.
    - Bunker delivery notes required.
    - Local supplier register.
    - Statutory fuel sampling.
- 19th May 2006: Baltic Sea SECA effective.
- 22nd November 2007: North Sea and English Channel SECA effective
- North American ECA, including most of US and Canadian coast (NOx & SOx, 2010/2012).
- US Caribbean ECA, including Puerto Rico and the US Virgin Islands (NOx & SOx, 2011/2014).

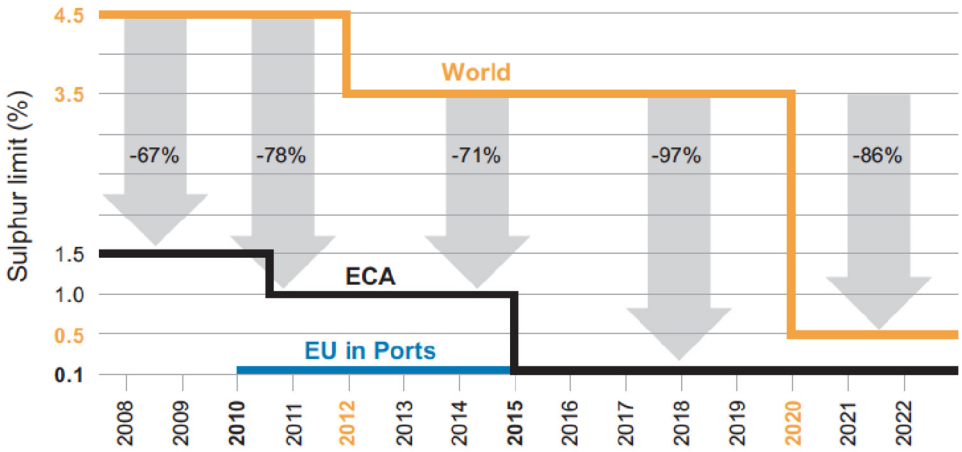

Figure 1: - Step down reduction in Sulphur limits

1.2 EU Directive

Presently Directive 1999/32/EC only limits the Sulphur content of marine gas oils used within EU territory to 0.2 % since July 2000.

The main features of the new "**Directive 2005/33/EC** of the European Parliament and Council modifying Directive 1999/32/EC about the sulphur content of marine fuels" are:

1. Adopted by the EU Parliament 13.4.2005.

2. Published in the EU Official Journal L191 22.7.2005.
3. Enters into force 11.8.2005.
4. Provides new Sulphur limits in marine fuels for ”fuels used” and for ”fuels placed on the market”.
5. Permits emission abatement technology as an alternative.
6. Provides a special clause for warships.
7. Invites a new proposal to be submitted by the EU Commission by 2008, possibly with a second stage of Sulphur limit values (possibly down to 0.5 %) and additional Sulphur emissions control areas.

1.3 Overview of the IMO & EU Standards – Sulphur Calendar

Table 1 below shows applicable low S limits as stipulated by IMO & EU

Table 1

	IMO			**EU**		
	2010	**2015**	**2020**	**2010**	**2015**	**2020**
Non-SECAs	4.5%	**3.5%**	**0.5%***	**-**	**3.5%**	**0.5%***
SECAs	**1.0%**	**0.1%**	**0.1%**	**1.5%**	**0.1%**	**0.1%**
At berth	**-**	**-**	**-**	**0.1%**	**0.1%**	**0.1%**
PAX Ships	**-**	**-**	**-**	**1.5%@**	**1.5%@**	**0.1%**

(* will come into effect from 1st January 2020, @ - Outside SECA areas)

1.4 Adoption and Implementation of low Sulphur fuel (0.5%)

The essence of various decisions that were taken by IMO Committees and Sub-Committees regarding enforcement of effective date of low Sulphur fuel from 1st January 2020 and further deliberations that will take place subsequently is captured in figure 2 below. The decisions taken have been briefly enumerated

1.4.1 In October 2016, MEPC 70 took the landmark decision of enforcing 0.5% Sulphur fuel globally thus advancing the date significantly from 2025.

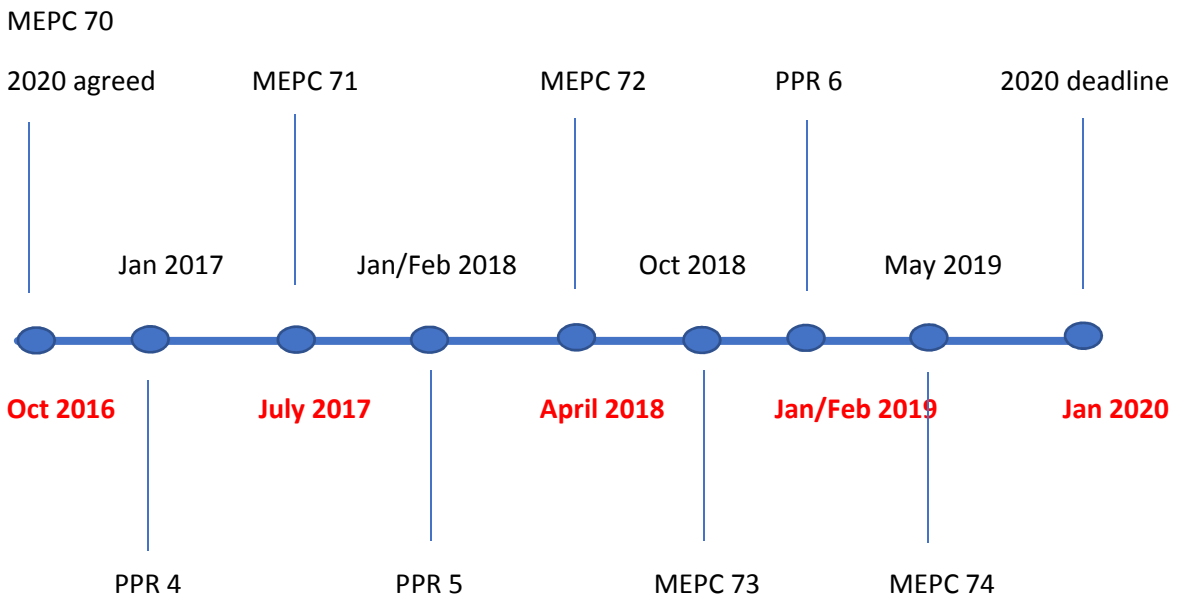

Figure 2:-Timeline of critical meetings for IMO 2020 implemetation plan

1.4.2 In January 2017 safety elements in relation to use of Low Sulphur fuel were discussed and upon receiving instructions form MSC 97 prepared a draft output (work programme) for approval by MEPC 71

1.4.3 MEPC 71, held in July 2017 took number of decisions which will have a significant impact on the current practices in the industry. Key decisions pertaining to 2020 low S fuel were:

- Proposed draft amendments to MARPOL Annex VI to develop a unified fuel verification procedure for different kinds of fuel oil samples
- PPR 5 will develop procedure as part of 2020 low Sulphur implementation action plan
- PPR 5 will deal with safety issues as instructed by MSC 98
- Intersessional meeting proposed in mid-2018

1.4.4 PPR 5 held in February 2018 took a step forward in implementing 2020 low S action plan made further progress by agreeing to present and review draft text of the following key documents at PPR6 (Feb 2019) to progress and subsequently finalise;

1. Guidelines for consistent implementation of the 0.50% Sulphur limit under MARPOL Annex VI
2. Amendments to the guidelines for on-board sampling for the verification of the Sulphur content of the fuel used on board ships
3. Amendments to MARPOL on sampling points and fuel analysis methodologies
4. Amendments to (Resolution MEPC.181(59)) to the 2009 guidelines for Port State Control officers under revised MARPOL Annex VI
5. PPR5 principally agreed the proposal of banning of non-compliant fuels on-board after the implementation date which is expected to come into force from March 2020

1.4.5 MEPC 72 held in April 2018 made further progress:

- Approved amendments to MARPOL Convention subject to final adoption pertaining to prohibiting carriage of non-compliant fuel, i.e. fuel having more than 0.5% Sulphur.
- No conclusion was reached regarding prohibiting either carriage of fuel as HFO or low Sulphur fuel in Arctic region

1.4.6 PPR Intersessional Meeting on Consistent implementation of regulation 14.1.3 of MARPOL Annex VI (ISWG-AP 1), was held from 9-13 July 2018 with a view to develop draft guidelines for approval by MEPC 73 to be held in October 2018. The draft MEPC circular on *Guidance on the development of a ship implementation plan for the consistent implementation of the 0.50% **Sulphur** limit under MARPOL Annex VI* includes sections on:

- Risk assessment and mitigation plan (impact of new fuels);
- Fuel oil system modifications and tank cleaning (if needed);
- Fuel oil capacity and segregation capability;
- Procurement of compliant fuel;
- Fuel oil changeover plan (conventional residual fuel oils to 0.50% Sulphur compliant fuel oil); and
- Documentation and reporting.

Further MSC 100 will also consider issues concerning safety implications associated with the use of low-Sulphur fuel oil,and take action as appropriate noting the initiative of industry organizations to develop industry guidance and possibly training material.

In addition, the intersessional meeting developed:

- draft amendments to MARPOL Annex VI on the definition of "sulphur content",
- "low flashpoint fuel",
- sampling of fuel oil used onboard, and testing and verification procedure for in-use fuel oil samples;
- development of draft amendments to update the *2009 Guidelines for port State control under revised MARPOL Annex VI* (resolution MEPC.181(59)) and *Guidelines for onboard sampling for verification of the sulphur content of the fuel oil used on board ships* (MEPC.1/Circ.864).

These will be further developed and finalized during the next PPR 6 session in February 2019.

The scheduled MEPC 74 Meeting in May 2019 will be crucial one, which will decide on the road map to implement 2020 low Sulphur (0.5%) fuel.

2.0 What are the options available to shipowners/Managers and possible alternatives

The ship owner has several options available from which he can address the challenges of meeting low Sulphur fuel on his fleet profile to sustain commercial viability of operation. The options available are:

i) Switch to compliant low Sulphur fuel as per IMO regulation to operate ships globally and continue to use 0.1% S fuel in ECA. Address the operational problems likely to be encountered in using low S (0.5%) fuel system, which will include

- Low viscosity
- Lubricity – lack of this will result in sticky plunger-barrel, fuel injectors
- Cat fines
- Choice between positive displacement (PD) pumps and centrifugal (CF) pumps.
- Maintaining of correct fuel oil temperature to prevent gassing

- Availability of compliant fuel at all bunkering ports
- Economic viability of as a consequence of transition to low S fuel.
- Cleaning of tanks before receiving low Sulphur fuel to avoid Sulphur contamination

ii) Continue to use 3.5% HFO in combination with Exhaust Gas Cleaning System (Scrubber). In this instance the EGCS is to be designed to handle different grades of fuel oil. In addition, initial investment(CAPEX), i.e. cost of capital, the operating cost (OPEX) and payback period must be considered before making a choice.

iii) Use of Marine Gas oil (MGO) DMA Grade and Marine Diesel Oil (MDO) DMB Grade as per ISO 8217. Switching over to these grades of fuels will comply with the regulatory requirement of using low S fuel, but in the long run, both grades of fuel oil will pose issues such as:

- Dealing with catalytic fines.
- Lubricity
- Cylinder lub oil, with optimum TBN value suitable for LSFO
- Temperature gradient if change over between HFO & LSFO is not affected in line with the engine manufacturer's instructions.
- Risk of MGO evaporating/gassing due to lower flash point.
- Inherent instability low Sulphur fuel poses threats to safe marine engine operation.

Switching over to MGO will definitely add to the operational and voyage costs, nearly to the tune of 25 to 30% more than that of using 3.5% S HFO.

iv) Use of LNG as fuel: LNG is considered as an attractive fuel alternative, but it is besieged with its own inherent problems, which are, to name a few:

- Availability of LNG infrastructure, worldwide to fulfill bunkering requirements
- Lack of supply chain for distributing the fuel
- Risk of potential hazards as a result of exposure of equipment or body to cryogenic liquid
- More volume required to carry same amount of LNG as HFO, thus reducing freight earning capacity of the vessel
- Double walled gas feed piping for engines
- Requirement of enhanced safety

- Gas tight compartment for engines having minimum number of air changes to ensure adequate ventilation
- Emissions of unburnt methane (known as “methane slip”) are detrimental due to “global warming potential” of methane being 28 times higher than that for CO2 over a 100 years perspective.

v) Other alternative fuels – Ethanol and Methanol are not considered since these are in the development stage

3. Specific Challenges/Risks in complying with 0.5% S Fuel]

Though many alternatives are available to overcome the use of 2020 low S fuel challenges, it is an onerous task to optimize the solution from the few available ones, the long-term solution which is sustainable to a ship operator must be ship specific and cannot be a generalized one. The following section deals with the challenges posed by use of low S fuel and how to mitigate them within the given framework of currently available alternatives. Also identified are risks/challenges associated with low S fuel which the main engines, the auxiliary engines and boilers have to use to satisfy the MARPOL limit, in implementing the regulation.

3.1 Lack of lubricity

Lubricity is defined as the ability to generate a hydrodynamic lubrication film. While lack of lubricity was never an issue when diesel engines operate on HFO or MDO, reduced lubricity in low S fuel poses a serious operational issue to marine fuel pumps. These pumps exhibit excessive wear and premature failure. In order to ensure that the fuels used have adequate lubricity value, ISO Std. 12156 stipulates High Frequency Reciprocating Rig test which requires a maximum wear rate of 460 microns. (Higher the value lower is the lubricity). The naturally occurring polar compounds in diesel fuel are nitrogen and oxygen which provide a protective layer on the metal surface resulting in boundary lubrication. However, the desulphurization process which removes Sulphur from diesel fuel also removes these polar compounds. This diminishes the lubricity characteristics of fuel oil which results in wear and tear of fuel pump elements, such as plunger, barrel and fuel injectors. Lubricity may be enhanced by addition of additives.

It is evident that to maintain hydrodynamic lubrication condition the low S fuels must have a viscosity range of 12-16 centistokes. This ensures that when two surfaces are in motion with each other, they are separated by a liquid film that carries the applied load. Viscosity of MGO lies in the range of 1.5 – 3.0

centistokes, which will lead to boundary lubrication and eventual metal to metal contact between the two moving surfaces.

The simplest way to ascertain the lubricity of the low S fuels is by determining Sommerfeld number, which is a function of the viscosity.

$$S = \left(\frac{r}{c}\right)^2 \frac{\mu N}{P}, \text{ where,} \qquad 1$$

S is the dimension less Sommerfeld number

r - radius of the shaft

c – radial clearance

μ - viscosity

P – Pressure or load per unit bearing area

N – revolutions per minute

The relation between Sommerfled number and friction in different lubrication modes is shown in figure 3 below

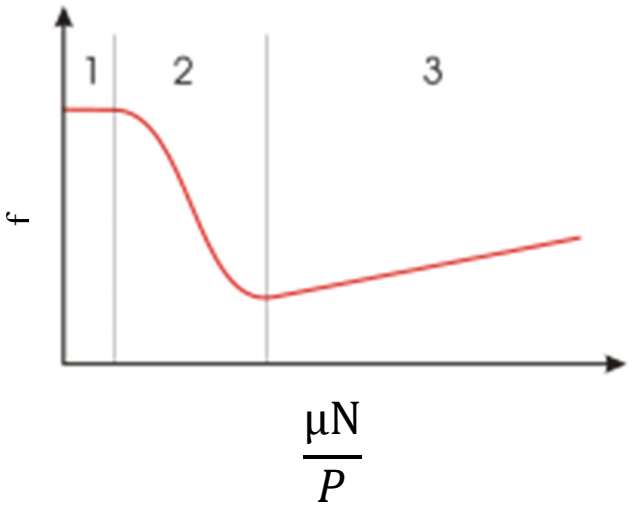

Figure 3: - Stribeck curve

From the above curve three lubrication regimes can be identified as follows:

1. Boundary lubrication
    - Solid surfaces come into direct contact, load supported mainly by surface asperities, high friction
2. Mixed lubrication
    - Some asperity contact, load supported by both asperities and the liquid lubricant.
3. Hydrodynamic lubrication

    - Negligible asperity contact, load supported mainly by hydrodynamic pressure

A higher number means a robust oil film

Gear and screw pumps used for transfer of fuel oil operate under boundary lubrication, else will result in wear and tear of pumping elements and loss of pumping pressure and volumetric efficiency.

3.2 Fuel oil Stability

Hydro-desulphurizing is employed to reduce amount of Sulphur present in fuel oil to an acceptable level. But in the process, this removes naturally occurring anti-oxidants, which provide physical and thermal stability. Thermal stability is an important requirement of diesel fuels not only from storage point of view but also as heat transfer fluid. The inherent instability of low Sulphur fuel poses serious threat to the safe operation of marine diesel engines, such as

- Degraded ignition quality
- Excessive engine deposits
- Increase in particulate emissions
- Fuel system fouling due to sludge formation

The effect of poor stability will manifest during prolonged storage on board ships by way of degradation, causing poor ignition quality and thus effecting engine operation.

3.3 Low fuel Viscosity

Low Sulphur distillates have viscosity ranging from 1.5 to 3.0 Centistokes. If appropriate viscosity is not maintained for satisfactory operation of fuel pumps, fuel injectors, it will have adverse effect on these elements resulting in excessive

wear, fuel pump plunger sticking. This occurs due to reduced oil film thickness due to low viscosity.

Low viscosity also results in leakage between fuel pump plunger and barrel, lower injection pressure These factors may give rise to starting difficulties and operations at low load.

The choice of fuel pumps while using low Sulphur pumps has an important bearing on the operational aspects of fuel system. It is evident that low S fuel has low viscosity, which poses in-numerable operational problems. Centrifugal pumps and positive displacement pumps behave very differently while dealing with low S fuel. Therefore, it is essential that fuel viscosity is to be maintained at optimum value to mitigate its influence on following pump performance parameters, especially the centrifugal pumps.

- Flow rate
- Efficiency
- Pressure
- $NPSH_R$

Figures below show the difference in performance between centrifugal and positive displacement pumps w.r.t. change in viscosity

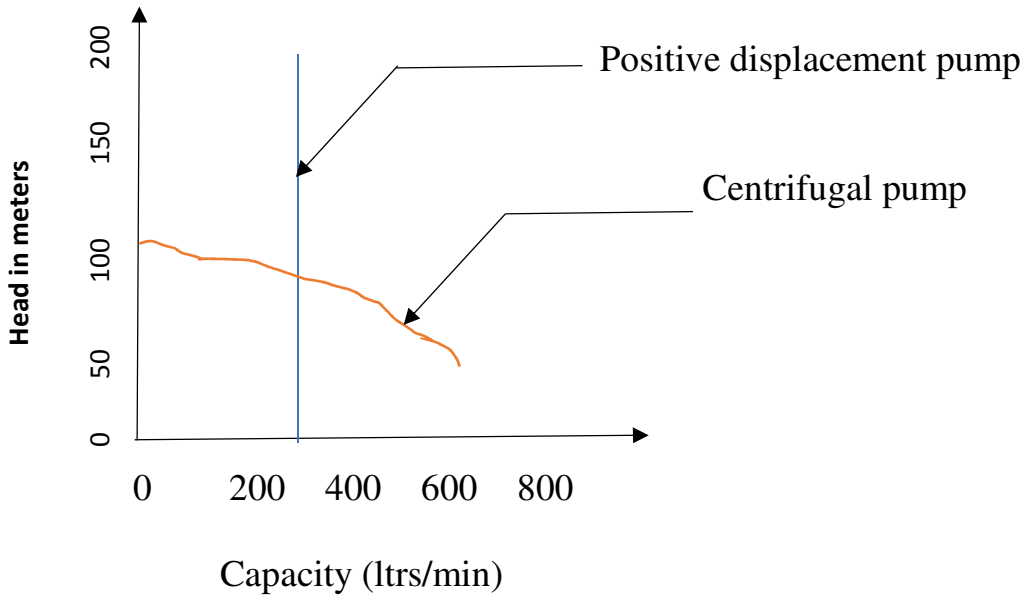

Figure 4: - Head vs. capacity

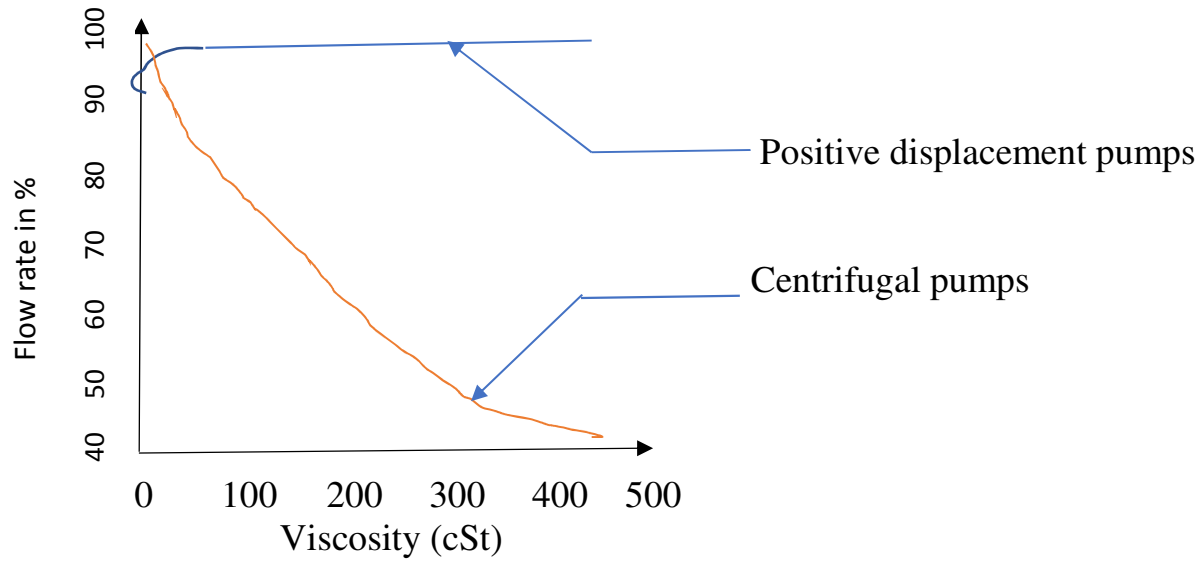

Figure 5: - flow rate vs. viscosity

Another factor which is to be kept in mind is centrifugal pumps operate optimally only at center of the curve, or what is known as **"Best Efficiency Point",** where as positive displacement pump can operate at any point on the curve.

3.4 Cylinder Oil for Low S Fuel

Diesel engines using HFO, require cylinder lub oil having Total Base Number of around 70 to neutralize acidic effects of 3.5% S present in the HFO. TBN, which is a measure of reserve alkalinity and higher TBN value is always desirable in countering the acidic effect of Sulphur. But this age old and proven practice of choosing higher TBN does not hold good when fuel is switched over to 0.5% S or even lower percentage of Sulphur. Higher TBN lubricant results in calcium salt deposits in combustion space and runs the risk of cylinder liner scuffing. Therefore, operationally it is prudent to have two-cylinder oil daily service tanks, one having TBN of 70 and the other having TBN of 25. This will facilitate changeover of cylinder oil tank depending on which fuel oil is being burnt, whether HFO or low S fuel oil

3.5 Catalytic Fines and Asphaltenes

These are aluminium silicates which are found in HFO and cannot be completely removed. Efficient separation and filtration removes these impurities to the extent of 80-90% of fines. ISO 8217 limits the cat fines to 40-60 mg/kg,but may vary according to viscosity.

3.6 Blending of fuels on board ship and Impact on tank Arrangement

Blending of fuels is an option available with the ship operator but blended fuel oils have their own issues or quality problems to tackle with such as:

- Instability
- Incompatibility
- Ignition and combustion difficulties
- Catalytic fines
- Flashpoint
- Viscosity

Proper precautions if taken w.r.t.

- Location of fuel tanks – low Sulphur fuel tanks not to be located next to HFO tanks, whose boundary walls are at a higher temperature
- Tank arrangement in such a way that will permit segregation of fuel tanks
- Never to blend high density fuel with low density fuel
- SOLAS compliance regarding number and capacity of daily service fuel tanks

Another important factor which the ship operator/owner should exercise due diligence while ordering bunkers.
It is pertinent to note that MARPOL Annex VI regulation 18.3.1.1, mandates that fuel used on board ships must be blends of hydrocarbons derived from petroleum refining. It is possible that with demand for low S expected to rise when 2020 Sulphur cap becomes applicable, bunker suppliers are likely to offer automotive diesel fuel containing bio-diesel as the only available option (Fatty Acid Methyl Ester; FAME, the most predominant bio-diesel. ISO 8217:2017 fuel specifies that FAME percentage is not to exceed 7%. In such a situation it would be prudent to seek help of engine manufacturers whether the existing ship board equipment such as purifiers, filters etc can handle such kinds of fuels.

4.0 Ship specific Implementation Plan

IMO has developed guidelines which every ship owner can take recourse to it while transiting to low S fuel by 1 January 2020. The development and adherence to a comprehensive and well-conceived ship specific implementation plan is of utmost importance to ensure that change over to compliant fuel is achieved as smoothly as possible. The development of this plan will mark a significant step taken by ship owner in meeting Port State and Flag State control checks. It may probably help the ship owner if he gets the plan reviewed by classification Society and by ships Flag state for adequacy and completeness.

While developing the ship specific plan the ship owner should carry out following steps to make it comprehensive and consider all the eventualities, which he may face when the deadline looms large over his head.

4.1 Risk Assessment and Mitigation Plan – this should deal with various factors such as which options to choose, availability of compliant fuels, operational problems, duration of operation using 0.5% S fuels, etc. This should form part of ship's safe management system.

4.2 Fuel oil system Modification and Tank Cleaning – Modifications to fuel system, which will include piping, choice of pumps, etc should be carried out in consultation with engine manufacturers and obtain approval from Classification Societies. Structural changes if required will also require class approval.

4.2.1 Fuel oils storage system – the need for dedicated fuel tanks for storage of low S fuel is to be decided by the individual ship owner. If ship requires that existing fuel oil tanks be converted permanently to low S fuel, the existing arrangement such as steam heating, trace heating will need to be isolated and blanked off permanently.

4.2.2 Fuel transfer, filtration and delivery system – Focus should be paid to avoid following potential problems, while dealing with low S fuel:

- Incompatibility of fuels bunkered from different locations
- Contamination due to return lines being led to incorrect fuel tanks, i.e. (low S fuel tank as against fuel tank with higher Sulphur content and vice versa)
- Preventing possible leaks occurring from pump seals and piping flange joints.
- Lubricity issue as highlighted in section 3.1 of this paper
- Vapour locks due to temperature variation when distillate fuels with low viscosity are used.
- Ship specific change over procedure, properly identifying change over valves, to be made available to ships' crew to facilitate change over from high S fuel to low S fuel.
- Provision of sampling on the bunker lines to take samples for testing of fuel oil supplied to ships.

4.3 Combustion equipment – Particular emphasis to be made fuel burning equipment of diesel engines and boilers**.** For IC engines**, v**iscosity at fuel inlets, correct grade of cylinder lub oils, change in the fuel injection system due to reduction in the energy density due to these fuels. Any modifications done to fuel injectors, or pump settings should be strictly in accordance with NOx Code so as

not to make EIAPPC invalid, this should be done as per allowable adjustment provided in the approved NOx Technical file with the concurrence of ROs

As far as boilers are concerned, possible design changes to fuel burning system could include,

- modification to burner arrangement, method of atomization (from steam to air)
- sensitivity of flame detectors – existing flame monitoring sensors may not be suitable for gas oil, because of the differing spectral emission ranges, which may result in activation of false alarm, leading to boiler shut down
- modification to heating system, including trace heating system
- Adjustment to air/fuel ratio due to higher calorific value of low Sulphur fuels than that of residual fuels(HFO).

5.0 Tank cleaning – Cleaning of Tanks is decided on several factors, such as

- Grade of fuel expected to be bunkered
- Shipyard availability, if modification to existing fuel system arrangement is envisaged
- Extent of contamination
- Type of charter – BIMCO Charter party agreement, which is expected to be made available to ship owners that may help ship owners to seek compliant fuels
- Trade routes
- Bunkering arrangement

6.0 General & Financial Considerations

Use of low S fuel will increase operating cost of ship, as these fuels will be more expensive than conventional residual fuels. High costs of low S fuel will increase voyage costs. Choice between use of exhaust gas cleaning system or switching over to low S fuel can be undertaken only after performing Return of Investment(ROI).

To safeguard interest of ship owners, it is advisable to include BIMCO Fuel Sulphur Content Clause (BIMCO 2005).

7.0 Conclusion

While it is imminent that the requirement of switching over to low S fuel will take place from 1st January 2020, the transition to low S fuel will happen eventually. IMO has taken number of steps, including preparing guidance document, which will be adopted in MEPC 73 to mitigate the problems that may be envisaged by all the stakeholders

Notwithstanding the outcome of MEPC 73, which will be convened in October 2018, the ship owner would stand to benefit operationally and prepare him well, perhaps mentally too, if steps outlined in this paper and those outlined in the several industry guidelines are taken right now to embark upon his journey to comply with 2020 low S deadline.

An early decision will certainly prevent IMO regulation 2020 from "***Headache becoming Migraine"***

There is no ***SILVER BULLET*** Solution, or ***ONE SIZE FITS ALL Remedy***; each ship owner has to take a call considering all pros and cons, which best suits his operational and business needs and is sustainable in the long run.

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The views expressed are those of author and not to be attributed to IRS, with whom he has the privilege of having associated with.